Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 2

Friday 14 May 2021 (morning)

1 hour 15 minutes

Candidate session number

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

2221 – 6111

15 pages

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Iron may be extracted from iron (II) sulfide, FeS.

(a) Outline why metals, like iron, can conduct electricity. [1]

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(b) Justify why sulfur is classified as a non-metal by giving **two** of its chemical properties. [2]

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(c) Iron (II) sulfide, FeS, is ionically bonded.

(i) Describe the bonding in this type of solid. [2]

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(ii) State the full electron configuration of the sulfide ion. [1]

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(Question 1 continued)

(iii) Outline, in terms of their electronic structures, why the ionic radius of the sulfide ion is greater than that of the oxide ion. [1]

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(iv) Suggest why chemists find it convenient to classify bonding into ionic, covalent and metallic. [1]

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(d) The first step in the extraction of iron from iron (II) sulfide is to roast it in air to form iron (III) oxide and sulfur dioxide.

(i) Write the equation for this reaction. [1]

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(ii) Deduce the change in the oxidation state of sulfur. [1]

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(iii) Suggest why this process might raise environmental concerns. [1]

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(Question 1 continued)

(e) Explain why the addition of small amounts of carbon to iron makes the metal harder. [2]

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2. Iron (II) sulfide reacts with hydrochloric acid to form hydrogen sulfide, H_2S.

(a) (i) Draw the Lewis (electron dot) structure of hydrogen sulfide. [1]

(ii) Predict the shape of the hydrogen sulfide molecule. [1]

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(b) In aqueous solution, hydrogen sulfide acts as an acid.

(i) State the formula of its conjugate base. [1]

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(ii) Saturated aqueous hydrogen sulfide has a concentration of 0.10 mol dm^{-3} and a pH of 4.0. Demonstrate whether it is a strong or weak acid. [1]

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(iii) Calculate the hydroxide ion concentration in saturated aqueous hydrogen sulfide. [1]

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(Question 2 continued)

(c) A gaseous sample of nitrogen, contaminated only with hydrogen sulfide, was reacted with excess sodium hydroxide solution at constant temperature. The volume of the gas changed from 550 cm^3 to 525 cm^3.

Determine the mole percentage of hydrogen sulfide in the sample, stating one assumption you made. [3]

Mole percentage H_2S:

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Assumption:

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3. Magnetite, Fe_3O_4, is another ore of iron that contains both Fe^{2+} and Fe^{3+}.

(a) Deduce the ratio of Fe^{2+}:Fe^{3+} in Fe_3O_4. [1]

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(b) Iron exists as several isotopes.

(i) State the type of spectroscopy that could be used to determine their relative abundances. [1]

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(ii) State the number of protons, neutrons and electrons in each species. [2]

	Protons	Neutrons	Electrons
$^{54}_{26}Fe$	. . . . .	. . . . .	. . . . .
$^{56}_{26}Fe^{3+}$	. . . . .	. . . . .	. . . . .

(c) Iron has a relatively small specific heat capacity; the temperature of a 50 g sample rises by 44.4 °C when it absorbs 1 kJ of heat energy.

Determine the specific heat capacity of iron, in J g^{-1} K^{-1}. Use section 1 of the data booklet. [1]

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(This question continues on the following page)

(Question 3 continued)

(d) In acidic solution, hydrogen peroxide, H_2O_2, will oxidize Fe^{2+}.

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^{-}$$

(i) Write the half-equation for the reduction of hydrogen peroxide to water in acidic solution. [1]

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(ii) Deduce a balanced equation for the oxidation of Fe2+ by acidified hydrogen peroxide. [1]

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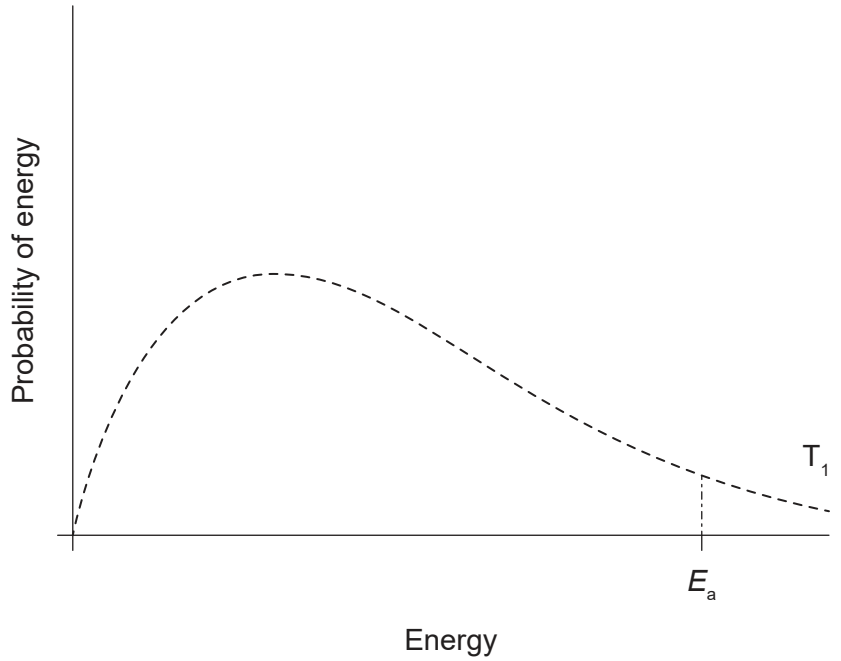
4. Hydrogen peroxide can react with methane and oxygen to form methanol. This reaction can occur below 50°C if a gold nanoparticle catalyst is used.

(a) The diagram shows the Maxwell-Boltzmann curve for the uncatalyzed reaction.

Draw a distribution curve at a lower temperature (T_2) **and** show on the diagram how the addition of a catalyst enables the reaction to take place more rapidly than at T_1. [2]



(b) The hydrogen peroxide could cause further oxidation of the methanol. Suggest a possible oxidation product. [1]

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(Question 4 continued)

(c) Methanol is usually manufactured from methane in a two-stage process.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$
$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(l)$$

(i) Determine the overall equation for the production of methanol. [1]

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(ii) 8.00 g of methane is completely converted to methanol. Calculate, to three significant figures, the final volume of hydrogen at STP, in dm^3. Use sections 2 and 6 of the data booklet. [3]

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(Question 4 continued)

(d) Consider the first stage of the reaction.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

(i) Determine the enthalpy change, ΔH, in kJ. Use section 11 of the data booklet.

Bond enthalpy of CO = 1077 kJ mol^{-1}. [3]

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(ii) State the expression for K_c for this stage of the reaction. [1]

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(iii) State and explain the effect of increasing temperature on the value of K_c. [1]

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will not be marked.

5. Ethanol is obtained by the hydration of ethene, C_2H_4.

(a) (i) State the class of compound to which ethene belongs. [1]

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(ii) State the molecular formula of the next member of the homologous series to which ethene belongs. [1]

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(b) Justify why ethene has only a single signal in its ^1H NMR spectrum. [1]

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(c) Suggest **two** possible products of the incomplete combustion of ethene that would not be formed by complete combustion. [1]

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(d) A white solid was formed when ethene was subjected to high pressure.

Deduce the type of reaction that occurred. [1]

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6. When dinitrogen pentoxide, N_2O_5, is heated the colourless gas undergoes thermal decomposition to produce brown nitrogen dioxide:

$$N_2O_5(g) \rightarrow 2NO_2(g) + \frac{1}{2} O_2(g)$$

(a) Suggest how the extent of decomposition could be measured. [1]

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(b) Data for the decomposition at constant temperature is given.

$[N_2O_5]$ / 10^{-3} mol dm^{-3}	Rate / 10^{-3} mol dm^{-3} min^{-1}
2.74	0.078
3.68	0.121
6.89	0.197
16.27	0.498
24.30	0.710

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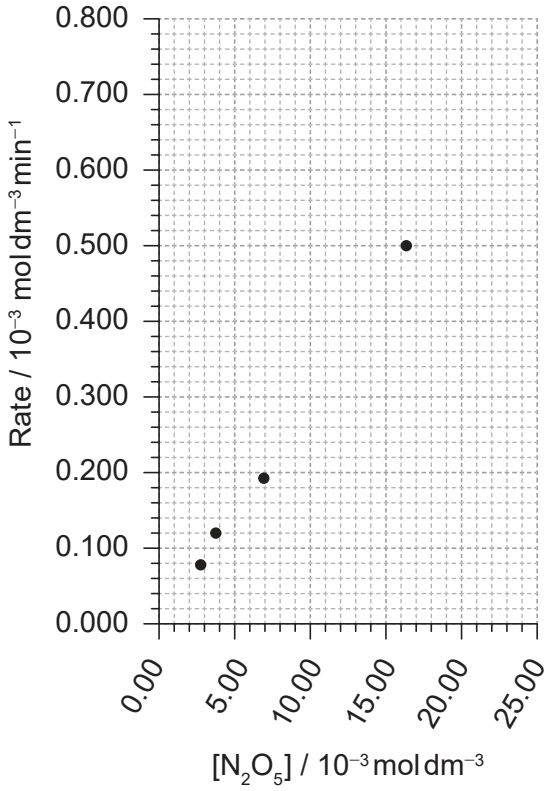
(Question 6 continued)

(i) Plot the missing point on the graph and draw the best-fit line. [2]



(ii) Deduce the relationship between the concentration of N_2O_5 and the rate of reaction. [1]

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(iii) Outline why increasing the concentration of N_2O_5 increases the rate of reaction. [1]

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References:

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